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TECHNICAL REPORT ECOM-02434-2

ACQUISITION AND TRACKING LASER COMMUNICATIONS SYSTEMS

QUARTERLY REPORT NO. 2

By

K. LANG, G. RATCLIFFE

MARCH 1967

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TECHNICAL REPORT ECOM-02434-2 MARCH 1967

ACQUISITION AND TRACKING
LASER COMMUNICATIONS SYSTEMS

QUARTERLY REPORT

1 October 1966 to 31 December 1966

Report No. 2

CONTRACT NO. DA28-043-AMC-02434(E)

DA Project No. 1P6-20501A-448 0607

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U. S. ARMY ELECTRONICS COMMAND, FORT MONMOUTH, N. J.

ABSTRACT

The major effort during the three-month period was directed toward the detailed design and construction of a beam steerer, beam-steering pick-off device, control circuits for the image dissector, and search/track circuits. All of these items are under construction and will be completed in time for an early test of the search/track capabilities of the system. Design work on the optical head is continuing.

FOREWORD

This report was prepared in accordance with Contract No. DA28-043-AMC-02434(E), DA Project No. 1P6-20501A-448 0607, dated 1 July 1966.

The technical goal of this program is the development and production of a two-station duplex laser communication system with automatic acquisition and tracking of each station by the other.

During this period the major effort was directed toward the detailed design and construction of a beam steerer, beam-steering pick-off device, control circuits for the image dissector, and search/track circuits.

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1. BEAM-STEERING MIRROR PICK-OFF DEVICE

1.1 Required Characteristics of Device

The beam-steering mirror pick-off device is the position feedback component which translates the angle of the beam-steering mirror into an electrical signal for use in the control circuits. The device is required to have the following characteristics:

1) linearity better than 5 percent

2) better than 100 microradian resolution

3) frequency response better than that of beam steerer

4) present little or no mechanical load to beam steerer

5) impedance compatible with simple transistor circuits

6) allow extension to two dimensions with minimum cross coupling

7) preferably nonmagnetic since beam sterrer has magnetic drive

8) axial vibration of mirror should produce no output signal.

Items 1), 2), and 3) can be related directly to the requirements for generating a satisfactory search pattern. If the pick-off device were nonlinear with, for example, a larger output at small mirror angles than at large mirror angles, the search pattern would be more widely spaced in the center than at the edges. The resolution must be made less than the transmitted beam spread and the frequency response must be high enough to pass the highest frequencies of the search pattern.

1.2 Test of Device

An optical pick-off device (shown in Figure 1) which meets these requirements and is similar to the one mentioned in the previous report[1] has been designed, built, and statically bench-

1. K. Lang, R. Lucy, and G. Ratcliffe, "Acquisition and Tracking Laser Communications Systems," Quarterly Rept. No. 1, Technical Rept. ECOM-02434-E-1; December 1966.

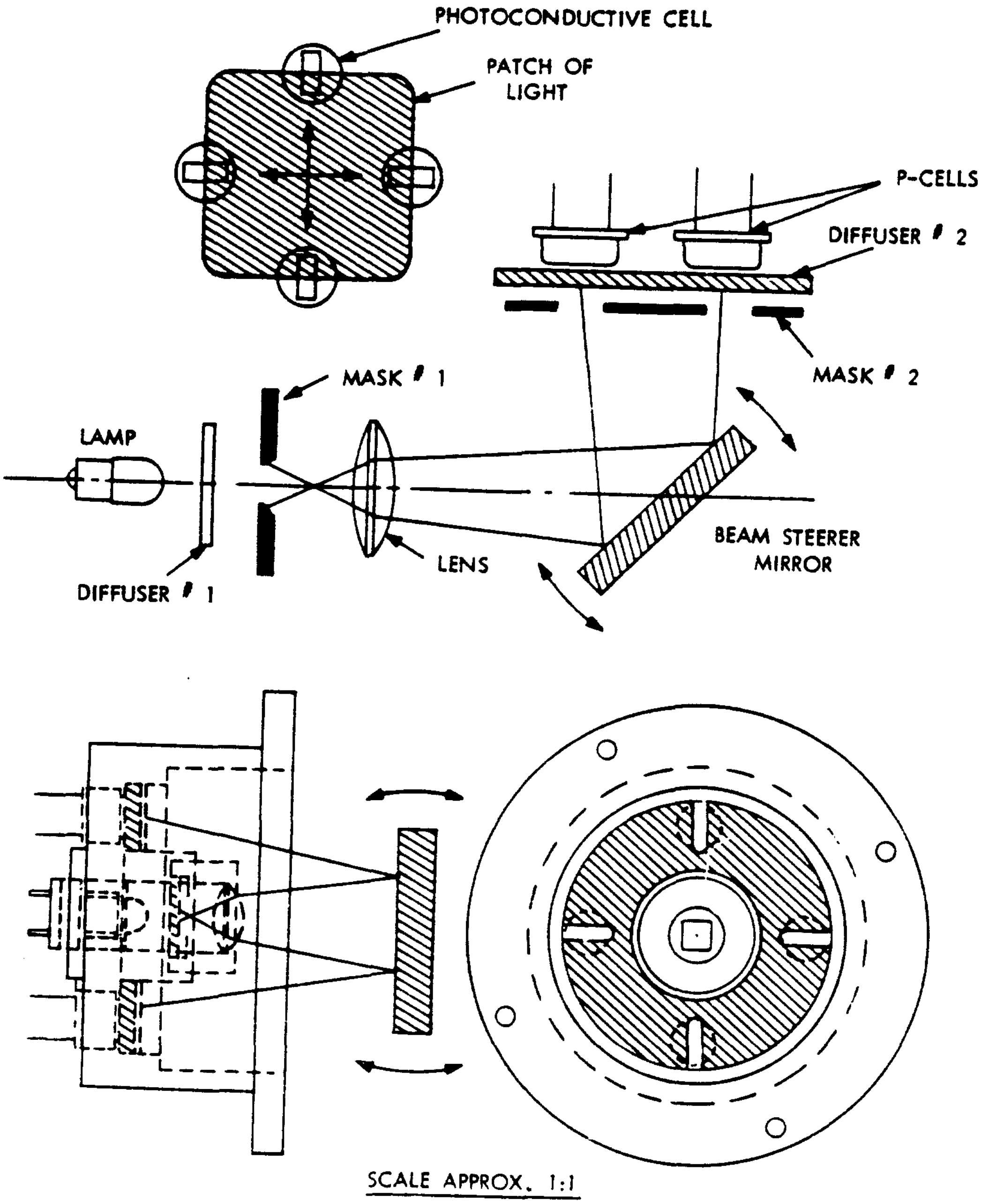

Figure 1. Angular Position Pick-Off

tested. A lamp illuminates a diffuser which is masked by a rectangle. The resulting bright object is focused onto another diffuser which is masked by four slits. Pairs of photocells behind these slits are arranged in bridge configurations so that the output of each bridge is a measure of the horizontal or vertical position of the image. Since the image is reflected by the back of the beam-steering mirror (the same surface which steers the transmitted beam), the output of the bridge is a measure of the angle of the mirror. Initial tests indicate a linearity of better than 5 percent and cross coupling less than 3 percent of maximum signal. The photocells are Raytheon type EM-1502 with a frequency response of more than 1 kHz.

Because the transmitted laser beam passes near the photocells of the pick-off device, a test has been made to determine whether light scattered from dust particles will add unwanted transients to the control system. A geometry similar to that of the pick-off device was arranged and a 30 mW beam about 1/8-inch in diameter was passed in front of the detectors. The bridge was supplied with 25 volts. It was found that smoke particles had little or no effect, but large dust particles (of the floor-sweepings type) caused spikes of 50 to 100 mV of duration 0.1 to 1 ms. Such effects are not expected to be detrimental to system performance.

The pick-off device seems to be satisfactory and we will test it in conjunction with an operating beam steerer in the near future.

2. BEAM STEERER CONSTRUCTION

A beam steere almost identical to the one described in the previous report, is under construction. The armature, supporting spring, magnet, and coil are shown in Figure 2. It was difficult to decide whether the main casting that houses the coils and magnets should be made of iron or aluminum. On the one hand, iron would be better because the flux lines through the armature could be closed through the casting. On the other hand, the iron shorts out some of the flux due to the permanent magnets. The irregular geometry makes calculation difficult, so castings of both iron and aluminum were procured from the same pattern. Initial tests indicate that aluminum castings will be used.

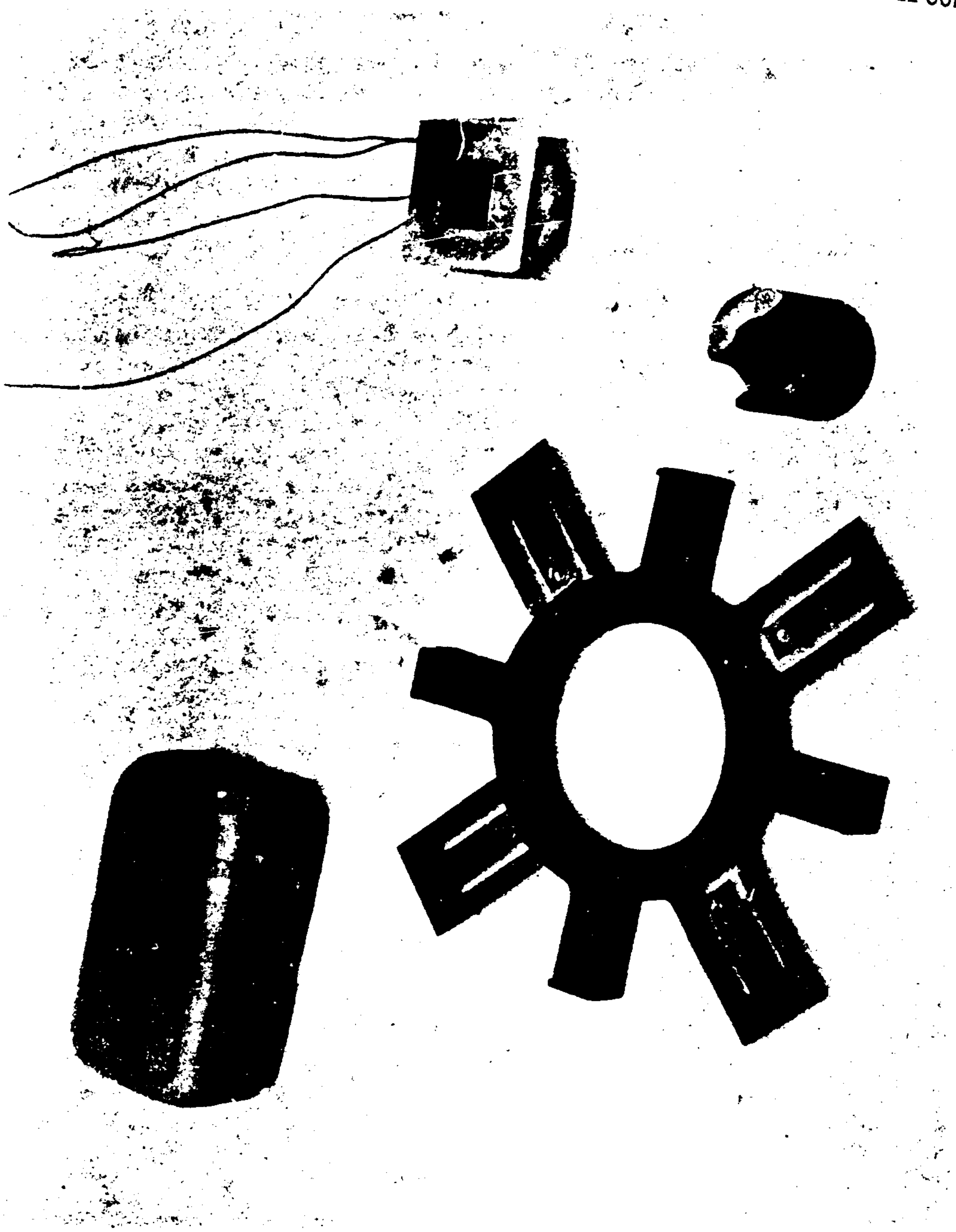

Figure 2. Beam Steerer Armature

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3. REARRANGEMENT OF OPTICAL HEAD COMPONENTS

The components within the optical head have been rearranged to a more compact arrangement. The new package is about 3.5 cubic feet in volume, almost a cubic foot less than the original design. The new optical head is shown in Figure 3. The optical diagram is shown in Figure 4. The final design will deviate very little from Figure 3. Detailed designs of the image dissector housing and some other components have been completed and are being manufactured.

4. DESIGN CHANGE INVESTIGATION

From time to time a question is raised as to why we do not plan to use the "Celestron" as the spotting scope. This would be accomplished by interposing a hinged mirror and eyepiece when this function is required. The fact that it may often be desirable to look through the spotting scope while the system is in operation makes this scheme impractical. Additionally, it is doubtful whether the cost of an eyepiece and hinged mirror would be less than the cost of a separate telescope. The spotting scope used will be a Bergen Type 2415 with a 1° field of view and a crosshair reticle.

As part of the layout work, attempts were made to simplify or improve the design. A small error in initial alignment will result from the displacement of the retroreflector from the geometrical center of the receiver optics. It would be possible to locate the retro to one side and use a large diagonal mirror at the center of the receiver, or even to place the retro farther back in the transmitted beam path. These possibilities are shown in Figure 5. However, both of these arrangements add complexity, cost, and volume, and will not be used.

5. IMAGE DISSECTOR CIRCUITRY DESCRIPTION

5.1 General

The image dissector, a standard ITT model FW-130, functions as a vernier tracking transducer in this application. A description of the dissector construction, specifications, and ratings may be found in the ITT manufacturer's data sheets. The star

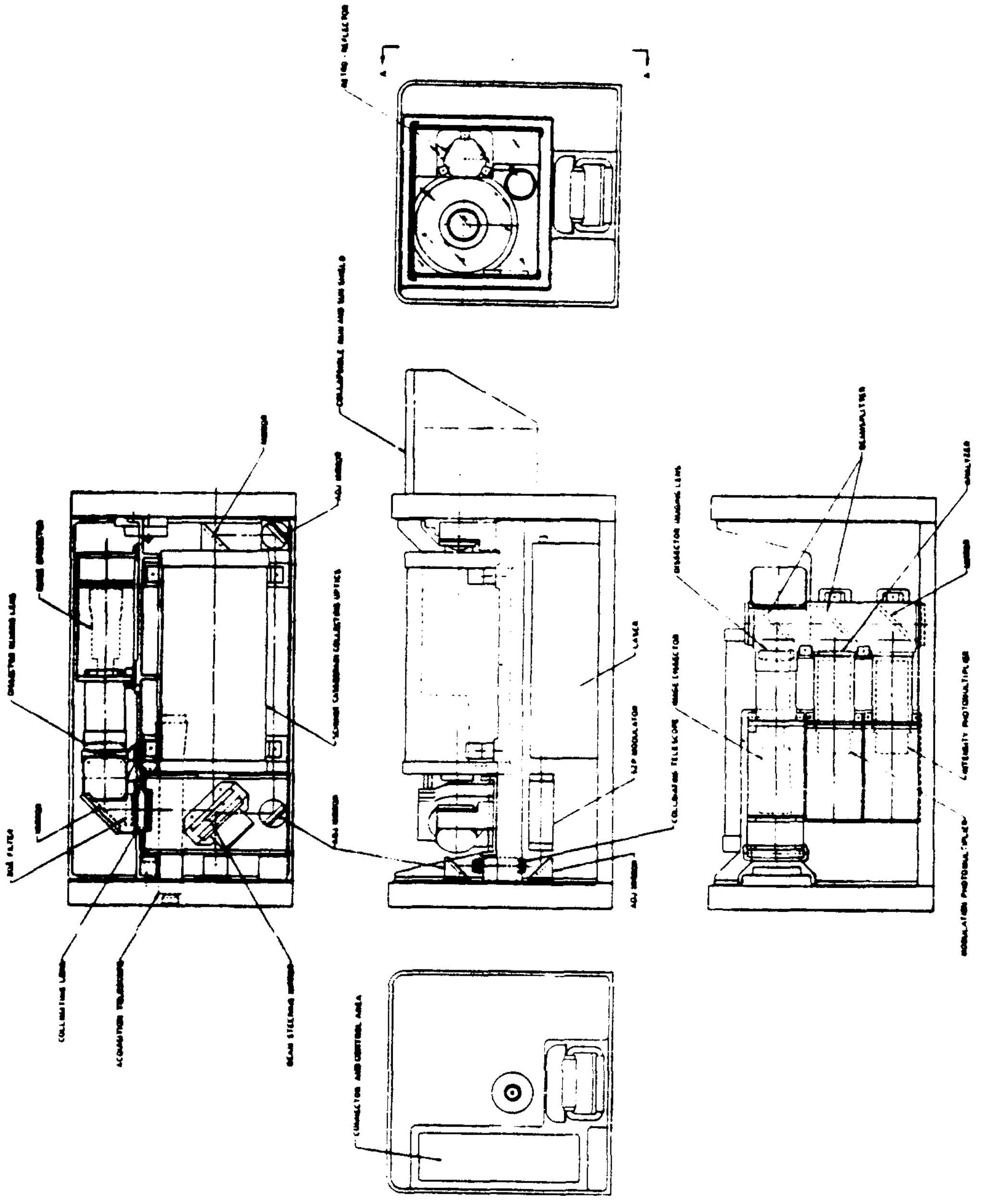

Figure 3. Optical Head (Preliminary Layout)

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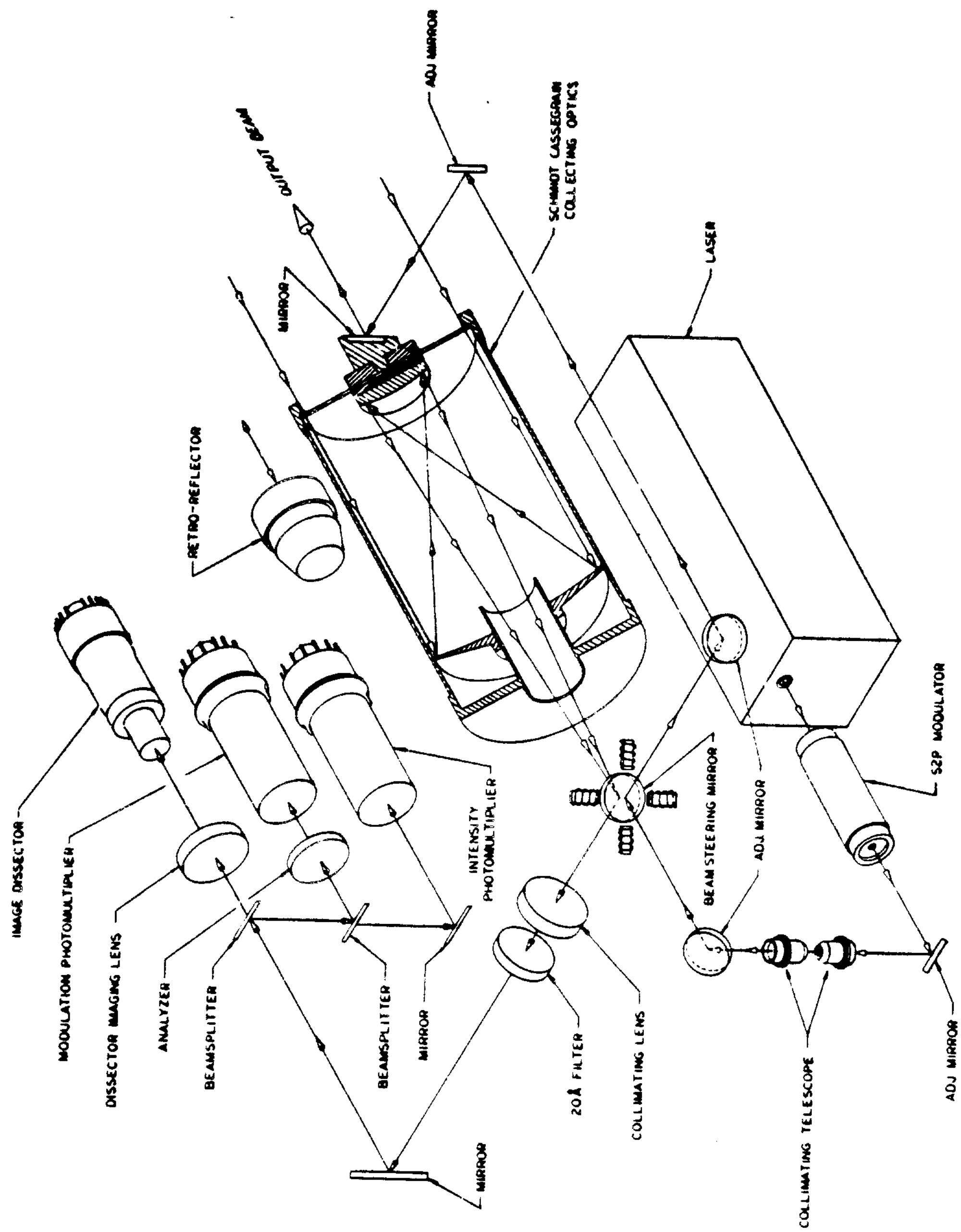

Figure 4. Diagram of Optical Head.

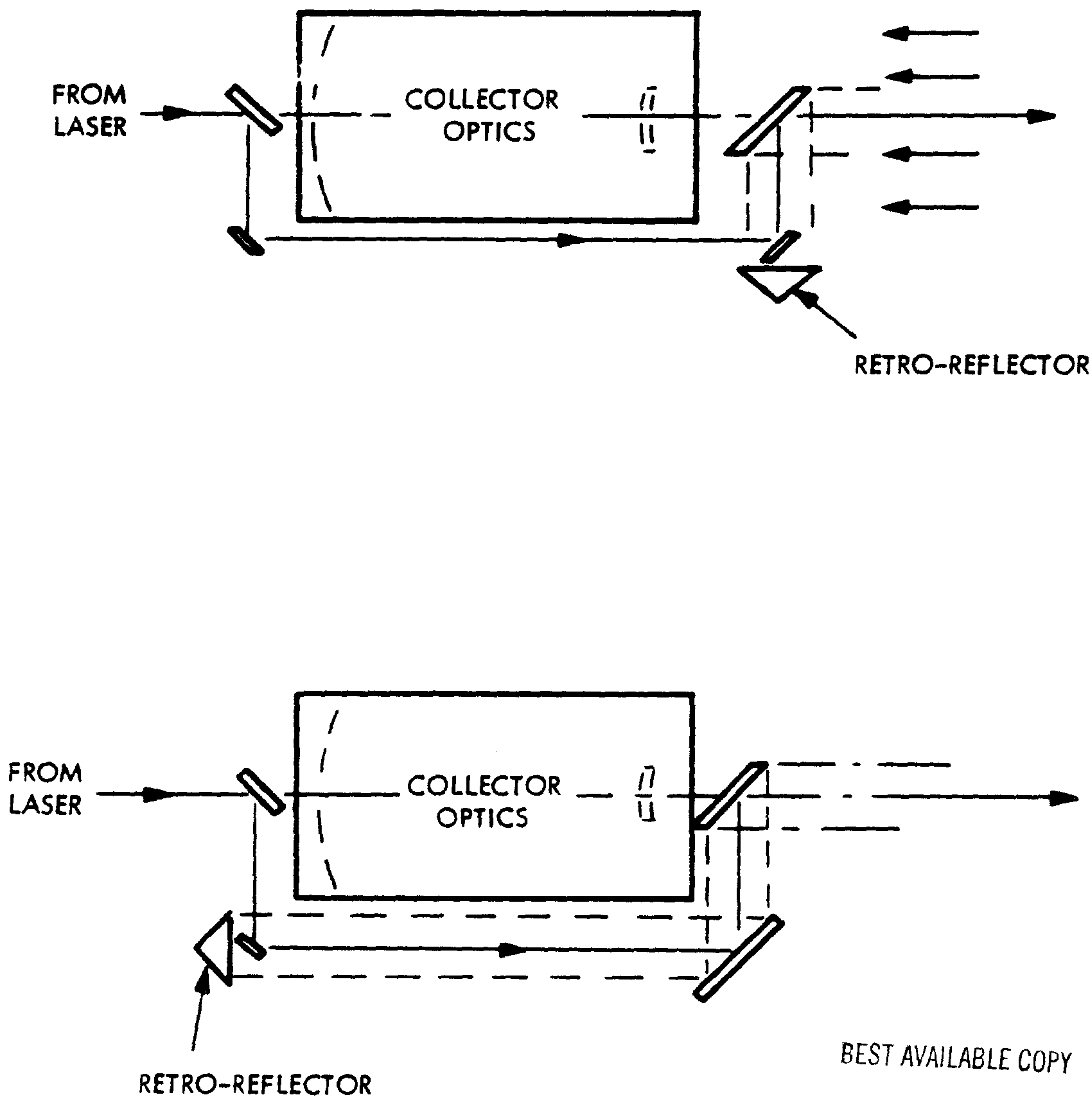

Figure 5. Arrangements to Bring Retro-Reflector to Optical Center

tracking scan mode a employed here is described (as a reprint of the referenced article) in the appendix of an earlier paper.[2] Attention here is placed upon the electronics associated with the dissector tube.

The image dissector electronics employ a combination of both analog and digital circuits, subsections of which are in integrated microcircuit form.

In order to facilitate construction and maintenance, circuit functions have been constructed on plug-in boards. There are three major circuit subdivisions:

1) the time base generator

2) the scan generator

3) the dissector error signal processing circuit.

The pulse timing and waveshape diagram of Figure 6, and the block diagram of Figure 7, illustrate the three major circuit function inter-relationships.

A more detailed discussion of the circuit subdivisions is presented in the following sections.

5.2 Time Base Generator

A modified Sylvania Syl-Pac clock card (No. 120) forms the basis for the timing generator.

Normally, the oscillator on this card is stabilized with a quartz crystal. The crystal is removed for dissector timing purposes and the oscillator is operated as a free running multivibrator. The frequency is adjusted to a nominal 8 kHz.

Output from the multivibrator is fed into a three-stage binary counter where it is counted down. As may be observed in Figure 6, timing pulses are made available at integral sub-multiple

2. R. F. Lucy, C. J. Peters, E. L. McGann, and K. T. Lang, "Precision Laser Automatic-Tracking System," Applied Optics, vol. 5, pp. 517-524; April 1966.

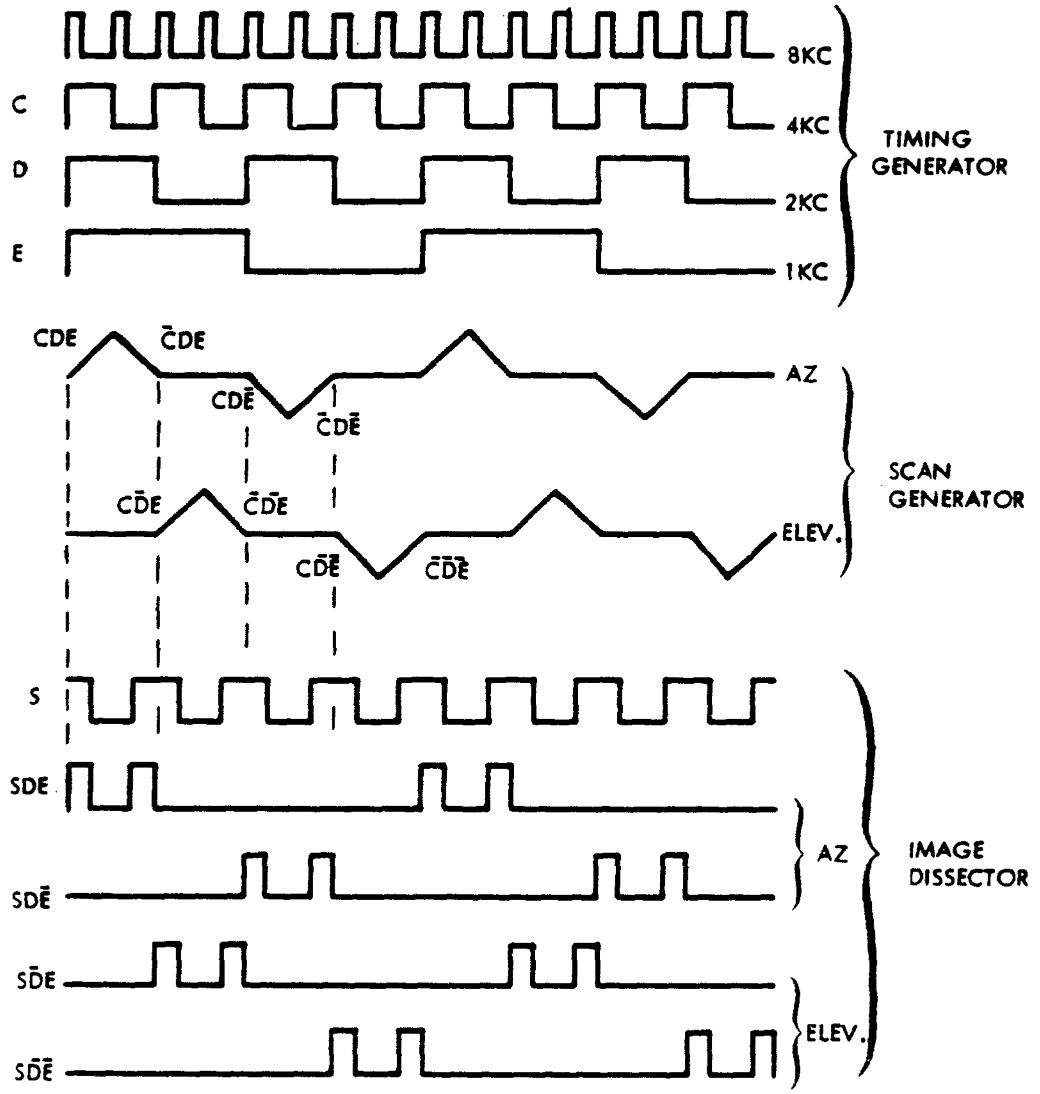

Figure 6. Timing and Waveshapes

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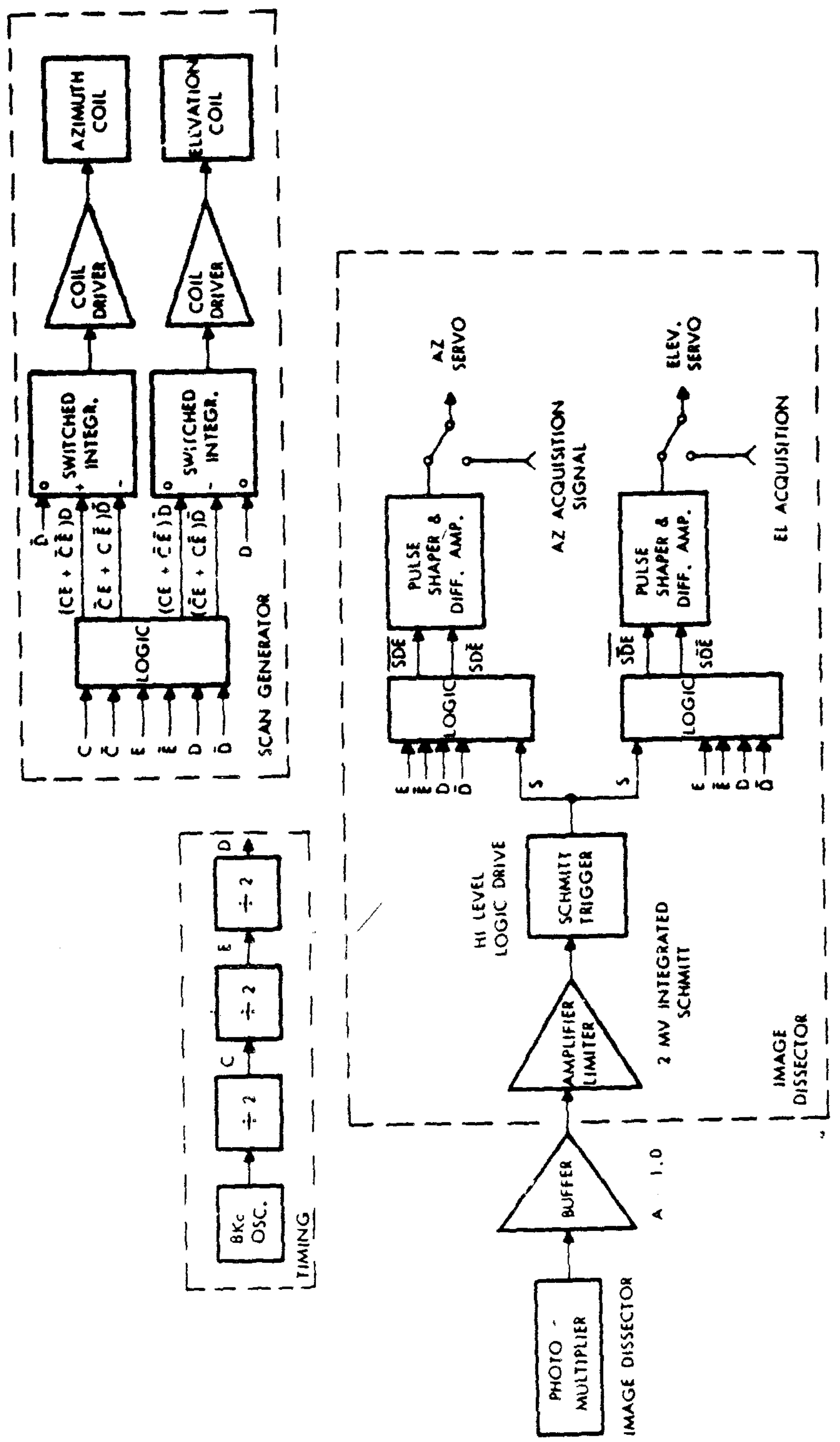

Figure 7. Block Diagram - Image Dissector and Associated Circuits

frequencies, 4 kHz, 2 kHz, and 1 kHz, by appropriate takeoff leads from the counter flip flops.

Output pulses from the counter proceed into appropriate gating logic to produce the scan and error detection waveforms.

5.3 Scan Waveform Generator

Generation of the scan waveform from the time base pulses is accomplished by switching a reference voltage source on and off. The reference voltage source output is integrated with a positive slope when on, and either a negative or zero slope when off.

Direct integration of the digital logic output is not feasible, since it lacks the amplitude precision and higher level required. The requirements of voltage precision and amplitude level are obtained from zener reference diodes placed at the outputs of the switching transistors.

The integrator capacitor voltage level is coupled into the high impedance, inverting input of an operational amplifier. Driving current for the dissector yoke is supplied directly from the output of the same operational amplifier, connected to act as a current source.

5.4 Error Signal Processing Circuits

Initially the image dissector output signal is amplitude limited and then proceeds into a unity gain operational amplifier, which acts as a buffer stage. The low drift operational amplifier provides cable driving capability and provides isolation necessary for the next circuit function (that of standardizing the input pulses).

A high speed dc comparator coupled with a Sylvania integrated circuit Schmitt trigger provides amplification and limiting of dissector signals. Limiting acts as a protection against overdriving levels, while the Schmitt produces a standard rise time pulse for a wide range of input levels. The Sylvania integrated logic circuitry following the Schmitt has requirements for both sharp rise time pulses and specific voltage levels, which the Schmitt provides. Schmitt output contains both azimuth and elevation information. Gate logic separates Schmitt pulses into sets of azimuth and elevation pulses.

Outputs from the integrated gate logic circuits, as shown on the waveform diagram of Figure 6, are pulse pairs of variable width. The degree of target pointing error directly determines pulsewidth, since the duration is determined by the time the electron image falls within the aperture.

Extraction of the error signal is accomplished by first inverting one pulse pair of a set, (azimuth or elevation). The positive and negative pulses of the set are then summed after having passed through a differential amplifier. The resultant difference signal is amplified and integrated by an operational amplifier with suitable feedback network constants. Output from the operational amplifier represents the filtered dc error signal, which proceeds to the input of the servo drive amplifier.

A similar process is applied to the complementary set of pulse pairs.

6. SEARCH PATTERN GENERATOR

During the search phase, the need exists to cover a relatively wide field (1° by 1°) with a narrow (50-arc second) transmitter beam. These two parameters establish the requirement for a precise search pattern containing a large number of elements. Driven mirror response time limitations, coupled with the large number of search elements, produce a low frame rate.

As in the case of the dissector electronics, construction of the search pattern generator has been facilitated by employing integrated digital and analog circuits constructed on plug-in boards. The search pattern is a step scan. An advantage of this pattern is its lack of flyback time.

The basis of the search pattern is a triangular waveform generator shown in Figure 8.

Generation of the triangular waveform is accomplished with a switched integrator. Switching of the integrator is obtained by employing positive feedback in a loop that includes an operational amplifier with large hysteresis.

Ramp slope and repetition rate are determined by the integration time constants, while the hysteresis determines the maximum amplitude. Output from the triangular waveform generator is

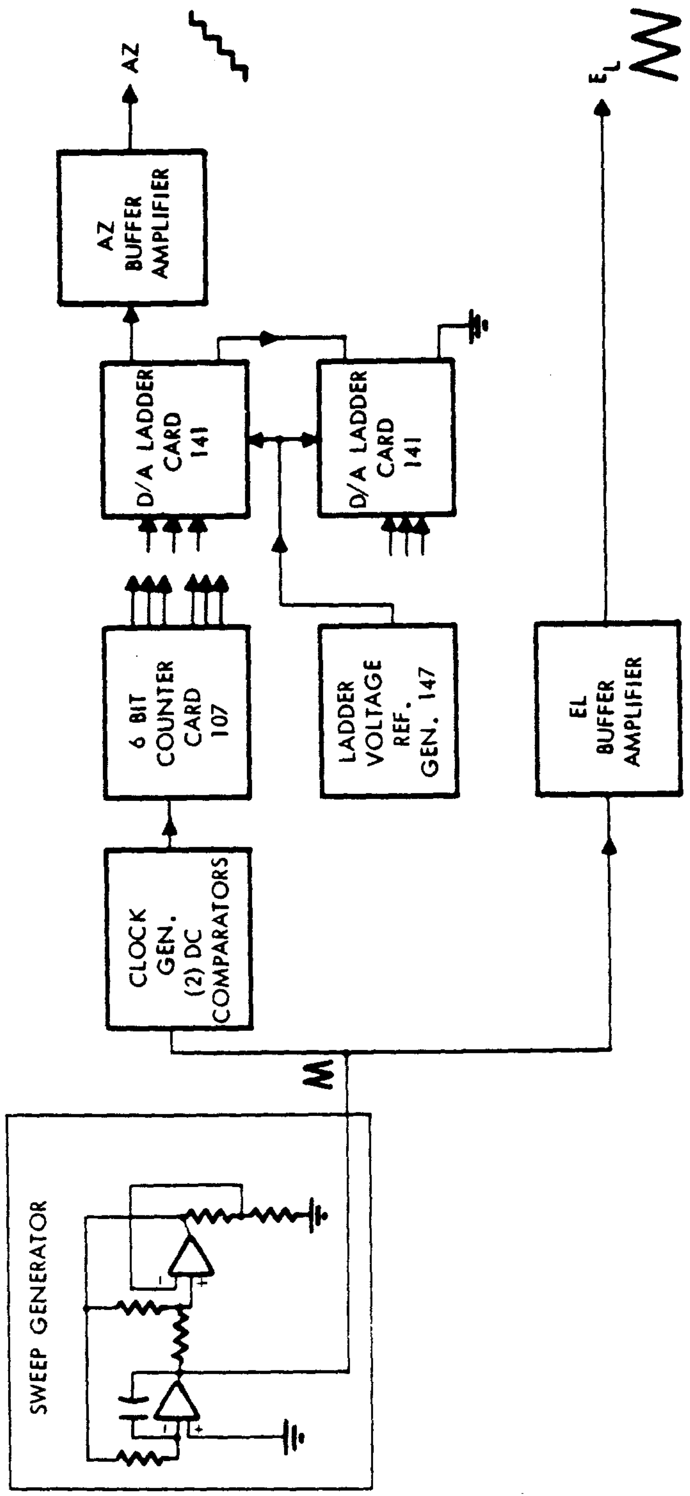

Figure 8. Step Scan Search Generator

put through a buffer amplifier and proceeds directly to the elevation servo amplifier input.

Two dc comparators are employed at the triangular waveform generator output to detect the apex of the triangles, i.e., the maximum and minimum waveform excursions. Comparator output pulses provide the clock input for the azimuth waveform generator, which is a six-bit digital counter. Counter output is transformed by a D/A ladder network into a staircase waveform. Ladder output (the staircase waveform) is coupled through a buffer amplifier to the azimuth servo amplifier input.

7. SEARCH/TRACK CIRCUITS

The requirement exists for establishing the proper moment for an automatic transition to vernier tracking from the acquisition mode. This system accomplishes the transition in the following manner.

Target presence is indicated by integrating a predetermined number of hits and exceeding a threshold. Output from the threshold circuit operates a relay driving amplifier, which energizes the servo amplifier input relays and transfers the servo from search to track.

Electronic circuits employed in the search/track function are also constructed on plug-in boards and incorporate the use of integrated microcircuits. A block diagram of the search/track function is presented in Figure 9. A more detailed description follows.

7.1 Synchronous Gating

As protection against noise and to further ensure response to true target hits, a degree of signal processing is accomplished as follows.

Outputs from the dissector clock generator and the dissector dynode chain are sent through circuits that standardize and buffer the signals preparatory to driving the gate logic.

At the gate logic output, the product of the two processed signals contains a dc term plus higher order components. It is the dc term of the gate output that is employed by the integrator in the next circuit function.

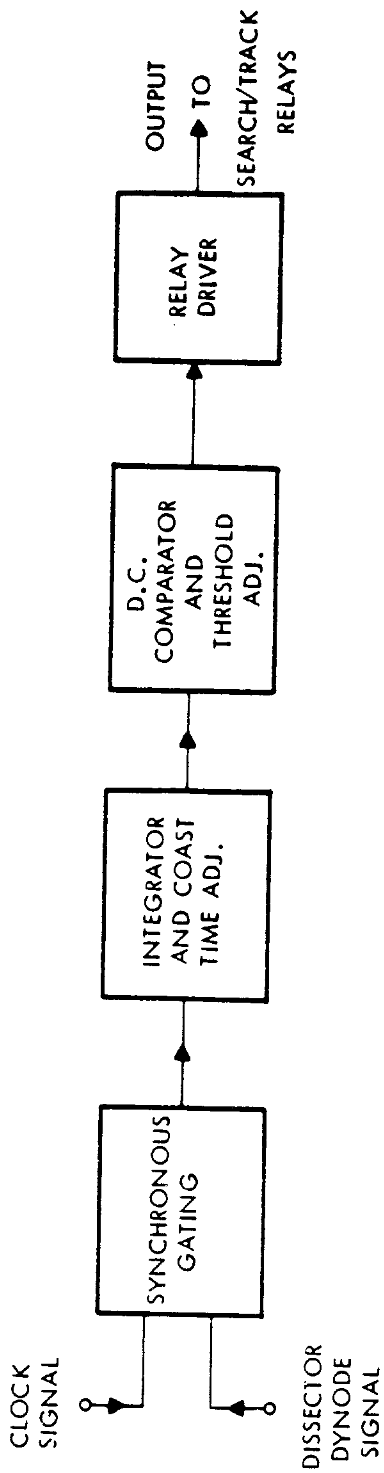

Figure 9. Search/Track Block Diagram

7.2 Integrator and Comparator

Output from the gates is integrated by a conventional resistance capacitance integrator. The time constant has been made long enough to ensure integrator linearity. Signal levels from the integrator are fed into the high impedance input of a dc comparator.

In order to provide a coast time, or delay, prior to restoring of the search mode after loss of target, the following technique is employed.

Integration of the input pulses is allowed to continue beyond the threshold level to a value set by a hold-off diode. Upon cessation of target signal, integrator output decay occurs until the threshold level of the comparator is reached, which takes about 10 seconds.

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